Superficial
Geology,
Medway

Denudation of the
Weald

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ON THE

SUPERFICIAL DEPOSITS

OF THE

VALLEY OF THE MEDWAY,

WITH

REMARKS ON THE DENUDATION

OF THE

WEALD.

BY

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OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN.

Contents.

Introduction.

During the last few years the subject of river-gravel has so much occupied the attention of geologists, that a short description of the gravel and brick-earth of the valley of the Medway will not be without interest, especially as those deposits have a most important bearing on the denudation of the Weald. In the present paper we propose, firstly, to describe the superficial deposits of the valley of the Medway, and, secondly, to show what light those deposits throw on the theory of the denudation of the Weald.

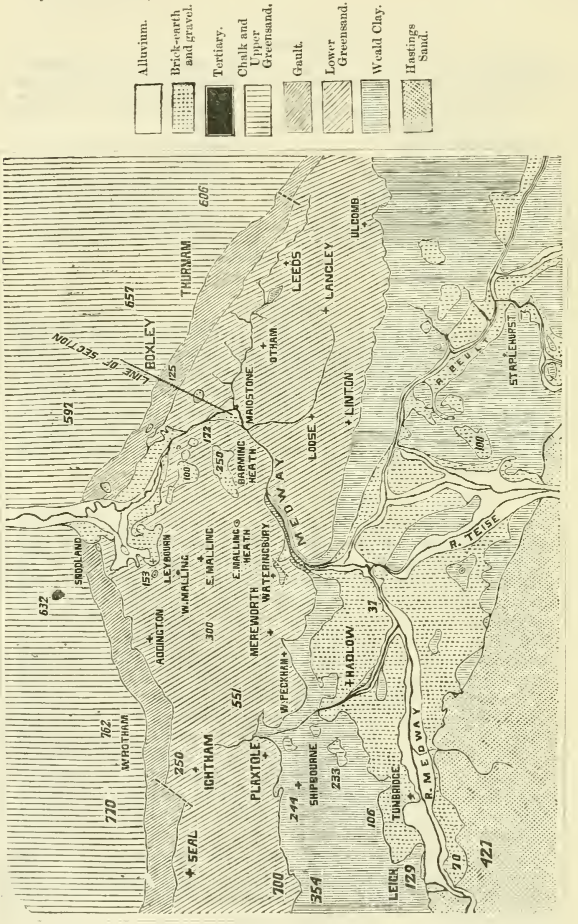
Part I. Description of the Superficial Deposits.

α. *General Description of the Valley of the Medway.*—Before describing the superficial deposits it will be well to devote a few lines to a concise account of the basin of the Medway; the position of the beds will then be more readily understood. As we intend to treat of only so much of the basin as lies within and south of the Chalk escarpment, we can confine our description to that part. The escarpment of the Chalk forms on the north a well-marked boundary to our district. On the east the line of watershed separating the valley of the Medway from that of the Stour passes south from the Chalk by Lenham to Pluckley and Shadoxhurst; thence the watershed turns westwards, and, passing Cranbrook, Ticehurst, Wadhurst, Crowborough, and West Hoathly*, divides the waters of the Medway from those of the Rother and the Ouse. From West Hoathly a line passing northwards by Copthorn Common and Bletchingley to the Chalk escarpment, north-west of Godstone, separates the Medway basin from that of the Mole; the boundary of our basin then follows the Chalk past Titsey, turns south-east and runs eastwards along the high ground of the Lower Greensand to Ightham Common, and then

* This high ground forms part of the prominent chain of hills known as the Forest Ridge. The highest point, Crowborough Beacon, is 804 feet above low-water mark.

Fig. 1.—*Geological Sketch-map of the Valley of the Medway and adjacent District.*

(Reduced from Sheet 6 of the Map of the Geological Survey of Great Britain: the Cretaceous beds surveyed by Mr. F. Drew, the gravels by Messrs. Foster, Topley, and Dawkins.)



Scale $\frac{1}{4}$ inch to 1 mile.

northwards to the Chalk near Wrotham, and is thus separated from the basin of the Darent.

The Chalk forms a steep escarpment facing the Weald to the south, but to the north and north-east the grounds lopes down gradually; the dip is everywhere into the escarpment, lower beds rising to the south. Through this escarpment the Medway flows at Burham. To the west of the transverse valley thus formed the strike is E. and W.; on the eastern side it is nearly S.E. and N.W. South of the Chalk we come upon the Gault, forming a flat of low ground averaging three-quarters of a mile in width. The Upper Greensand is here very thin, and makes no feature on the ground; springs often flow out at the base of the Chalk. The Lower Greensand rises gradually from beneath the Gault, and ends, like the Chalk, in a steep escarpment to the south. The upper part of the Lower Greensand is sandy (Folkestone Beds)*; this division is underlain by a thin bed of clay and sandy clay with fuller's earth (Sandgate Beds); and the lower part of the Lower Greensand (Hythe Beds) consists mainly of beds of limestone and sand, known as "Kentish Rag" and "Hassock." Here the valleys, which do not reach down to the Atherfield Clay, are often *dry*, like those of the Chalk. The Kentish Rag country east of the Medway is known as the Quarry Hills. Springs flow out at the junction with the Atherfield Clay below. This clay is the lowest member of the Lower Greensand, and rests immediately on Weald Clay, which occupies a low and broad plain, varying from four to seven miles in width. The Hastings Sand†, subdivided into beds of clay and sand, rises up on the south from beneath the Weald Clay towards the high land of the Forest Ridge. All the streams to the north of this ridge run into the Medway, those to the south drain into the Rother and the Ouse; the former enters the English Channel at Rye, and the latter at Newhaven.

The Medway is formed by the junction of a number of small brooks coming down from the high land near East Grinstead; it flows down past Hartfield to Penshurst, where it receives a large tributary, the Eden, and passing Tunbridge, arrives at Yalding. Here the Beult and the Teise fall into the Medway, which now enters the gorge cut in the Lower Greensand; it soon reaches Maidstone, receives the Len, and then flows on in a general north-north-westerly direction towards Snodland, where it is joined by the Snodland Brook. The Medway now takes its course along the gorge through the Chalk, passes by Rochester, and finally reaches the Thames at Sheerness.

β. Superficial Deposits.—The following different kinds of superficial deposits are found in the Medway valley:—

1. Subaërial beds.
2. Modern alluvium.

* For a description of the subdivisions of the Lower Greensand, see Fitton, Trans. Geol. Soc. 2nd ser. vol. iv. 1836, p. 103, and Drew, 'Memoirs of the Geological Survey,' Sheet 4, 1864.

† For a description of the northern part of the Hastings Sand country, see Drew, Quart. Journ. Geol. Soc. vol. xvii. 1861, p. 271.

3. River-gravel and brick-earth (Loess).

1. *Subaërial Beds* *.—Under this head we class those beds which are formed by rain before it has collected into streams.

In our area they are of two kinds—

(1.) Rainwash-brickearth and chalky wash.

(2.) Unstratified flint gravel and beds of angular chert.

(1.) The action of the weather is always degrading rocks, and the matter thus detached is carried down the hill-sides by rain. In some places this accumulates to a considerable thickness, and may then be conveniently termed "rainwash." When carried down into the streams it goes to form true alluvial deposits, or is carried away to sea.

It is frequently difficult to distinguish between rainwash-brick-earth, and true alluvial loam. Both may contain land-shells, and the former is sometimes roughly stratified, but rarely, if ever, so distinctly as the latter.

(2.) Beds of chemical origin left as the result of the chemical action of rain on the strata come under this head. The "dry valleys" of the Chalk have usually a considerable thickness of flints in their lowest parts. These flints are entire, or, if broken, are sharply fractured by weather, never rounded or water-worn. These valleys are probably due to the dissolving away of the Chalk along lines of underground drainage†. Deposits of flints also occur frequently on the top of the chalk downs, mostly mixed with clay (clay-with-flints); and this clay, too, is in most cases probably the residue of the chalk which has been dissolved away‡.

The beds of unstratified flint gravel that are met with in many places on the Lower Greensand, Gault, and lower slopes of the Chalk are probably the residue left, as the Chalk escarpment was gradually worn back by subaërial denudation. This gravel may be seen on Pennenden Heath, near Maidstone, for instance; it differs entirely from the river-gravel by its want of stratification, and by the absence of Wealden pebbles; and it consists of angular and subangular flints, with occasionally a few Tertiary pebbles, the interstices of the gravel being often filled up with clay. This gravel is sometimes very chalky, as is the case at a place about a mile N.E. of Aylesford, where the deposit is 15 feet thick and rests on the Gault.

2. *Modern Alluvium.*—The modern alluvium does not differ in any important respect from that of other rivers, and does not need any very particular description. It consists of loam and gravel. About Tunbridge and Yalding the alluvium forms broad meadows; between Yalding and Teston it gets quite narrow, and then disappears altogether until you have passed Maidstone. At Aylesford alluvial meadows are once more met with, forming a broad plain near Snodland.

3. *River-gravel and Brick-earth* (*Loess*).—River-gravel§ occurs

* See Godwin-Austen, Quart. Journ. Geol. Soc. vol. vii. p. 1851, 118.

† Whitaker, 'Mem. Geol. Survey,' Sheet 7, 1864, p. 96.

‡ *Ibid.* Sheet 7, pp. 63, 66, and Sheet 13, 1861, pp. 54, 55.

§ We have used the term "river-gravel" instead of "valley-gravel," in order to prevent the gravel of true river-origin from being confounded with the subaërial gravel which also occurs in the Medway valley.

at all heights, from the present alluvial plain up to 300 feet above it. It is not possible to draw any exact line between the higher and lower gravels. They form, as Mr. Prestwich says, "the extremes of a series." Much confusion has arisen in consequence of some observers employing the term "high-level gravel" to designate the higher terrace- or river-gravel of a country, whether occurring on the flanks of a valley or capping the neighbouring hills, whilst others restrict the term to the still higher gravels, which have no obvious connexion with the present drainage of the country.

The following table shows at a glance the terms used by some of the most recent writers on the subject:—

Prestwich, 1862*, 1863†. Lyell, 1863‡.	Prestwich, 1863†, 1864§. Lyell, 1865‖.	Whitaker, 1864¶.
Upland loams and gravels (Lyell).		High-level gravels.
High-level gravels	High-level valley-gravels	Valley-gravel: Terrace-gravels.
Low-level gravels	Low-level valley-gravels	Valley-gravel: Low-level gravels.

River-gravel and brick-earth are found overlying all the formations over which the Medway passes, sometimes forming broad spreads, in other cases existing only in small isolated patches. The most convenient way of treating the subject will be, in the first place, to describe the gravel and brick-earth of the Medway and its tributaries; then, to pass on to a special description of the pipes of gravel and brick-earth that occur in the Kentish Rag; and finally to notice a few interesting cases of disturbance.

a. *The Medway.*—The lowest gravel is seen at many places along both banks of the Medway. In the Hastings Sand country it generally consists entirely of pebbles of Wealden sandstone, but in other parts it often contains angular and subangular flints, Tertiary pebbles, and Wealden pebbles.

In some gravel at Maidstone, a few feet above the river, Professor Morris has found numerous species of land shells**.

The higher river-gravel of the Medway valley is far more interesting and important than that which occurs at a low level; it often lies in terraces, and is found at various levels above the river up to 300 feet; and, like the lower gravel, it always consists of rocks which occur within the Wealden area.

In following the Medway from its source we do not meet with any gravel of great importance until we reach the neighbourhood of

* Proc. Royal Soc. vol. xii. p. 38.

† Quart. Journ. Geol. Soc. vol. xix. p. 497. ‡ 'Antiquity of Man,' p. 107.

§ Phil. Trans. vol. cliv. 1864, p. 247.

‖ 'Elements of Geology,' 6th ed. p. 114.

¶ 'Mem. Geol. Survey,' Sheet 7, p. 68.

** Mag. Nat. Hist. vol. ix. 1836, p. 593.

Tunbridge *. Here, on the north of the Medway there is a plateau, several square miles in extent, covered by a deposit of gravel and brick-earth. About Hadlow the brick-earth predominates, and forms a rich soil of much value for the cultivation of hops. At Hadlow the level of this plateau is 40 or 50 feet above the river, and north of Hadlow it is nearly as much as 80 feet. A little east of Hadlow the ground slopes down gradually to the Medway, and the higher river-deposits join on to the lower without any distinct line of separation. In places the gravel and brick-earth have been cut through by small streams, which expose the Weald Clay beneath.

A good section of the gravel is seen at Goose Green, near Hadlow, where a pit shows 15 feet of gravel, which consists of pebbles of Wealden sandstone, angular and subangular pieces of flint and chert, besides Tertiary pebbles. False-bedded coarse sand is found interstratified with the gravel.

Brick-earth is dug at a place marked *Pottery* on the Ordnance Map; on the southern side of the pit stratified brick-earth 13 feet thick is seen, with scarcely a single pebble; a little further north false-bedded sand and gravel are interstratified with the brick-earth, and in one place there is an interesting case of disturbance, to which reference will be made later. Few other sections of brick-earth are to be had, as it forms such a good soil that it is more profitable to cultivate hops than to dig the earth for bricks.

North of Tunbridge several patches of gravel occur of considerable interest.

The outlier north-east of Starve Crow Farm is, at its highest part, 180 feet above the river at Tunbridge. This gravel has been much dug for roads: it appears to be 14 or 15 feet thick; the springs on North Fright Farm are at that depth. Other patches of gravel are found near here at about the same level.

Junction of the Plaxtole and Medway Gravels.—Just east of the village of Plaxtole the Greensand range is broken by a valley running northwards up towards the Chalk escarpment, which, however, shows no corresponding feature. Along this valley a stream runs southward to join the Medway.

About half a mile south-east of Plaxtole is a patch of gravel about 60 feet above the stream, in which we can clearly trace the junction of the old Medway with the old stream that flowed through the Greensand escarpment. Along the south of this outlier Wealden and Tertiary pebbles, with pieces of flint and chert, occur. The gravel is well seen resting on clay on the road going south from Plaxtole. A brickyard just east of this gave, in August 1864, the following section:—

	ft.	ins.
Gravel not well bedded	2	6
Good gravel interbedded with coarse sand and a little clay	4	0
Blue clay (Wealden)		

* There are beds of gravel higher up the Medway than Tunbridge, but not of sufficient importance to claim notice here. They will be described in the Memoir on Sheet 6 of the Geological Survey-map.

Wealden pebbles are less numerous here than in the road-cutting to the west. This deposit is certainly an old river-gravel of the Medway. On the east side of this outlier a different gravel occurs, and is seen along the road going north from Dunks Green. It contains flints and Tertiary pebbles, but *no Wealden pebbles*; at one point a fragment of *chalk* was found embedded in the gravel; many of the flints are rather angular and large.

It must be particularly observed that this deposit, which differs materially in its character from that on the south side of the outlier, overlooks the transverse valley before mentioned. The stream which comes down this valley from the north traverses only Greensand and the beds above; it can therefore only bring down materials contained in those beds. In this small patch of gravel, then, we have abundant evidence, in the absence of Wealden pebbles, in the large size of the flints, and the presence of *chalk* itself, that in former times, when the stream ran at some distance above its present level, it then, as now, came from the north, bringing down only materials belonging to beds found along its course. We have here preserved the exact junction of the small transverse stream with the main river, which then, as now, brought down débris from the west and south.

It may be well to notice a similar junction occurring further down the Medway. Between Allington and Aylesford we have, on both sides of the river, evidence of the junction of a stream with the Medway, when both were running 20 or 30 feet above their present level. Just under the railway-bridge, half a mile north-west of Allington Church, 8 feet of gravel is seen in the railway-cutting. The gravel is well stratified, and contains flints and chert with Tertiary and Wealden pebbles, besides numerous rounded fragments of chalk, which have been brought down by the stream which rises at the foot of the chalk hills near Boxley. From this gravel were also obtained fragments of concretionary Wealden ironstone containing small *Paludinæ*, also a piece of shelly ironstone *, with great numbers of *Cyclas* (or *Cyrena*). These specimens, were the Wealden origin of the pebbles disputed, would be sufficient to prove that materials derived from the central districts of the Weald are found in the gravels of the Medway †.

Similar interstratifications of chalky gravel, with gravel containing Wealden pebbles, are met with along the road just south-east of Cob Tree, near Maidstone. Prof. Morris, in the paper already alluded to ‡, has noticed the above section, and says that it is remarkable as containing pebbles of chalk, "although it occurs two miles from any chalk *in situ*."

Further down the Medway valley we come to an important spread of gravel, which forms a well-marked terrace near Aylesford.

* A bed of shelly ironstone, not to be distinguished from this, is found almost universally at the base of the Wadhurst Clay. Similar beds, perhaps, occur in the Weald Clay.

† This fact, obvious enough to any one acquainted with the Weald, was first published, we believe, by Mr. Prestwich, Phil. Trans. 1864, p. 267 and Map.

‡ Mag. Nat. Hist. vol. ix. (1836) p. 595.

The top of the terrace is rather more than 40 feet above the level of the Medway. The gravel-pit a little north-east of Aylesford Church will be known to many geologists, as it has yielded such an abundant harvest of Mammalian remains.

The gravel here is from 18 to 20 feet thick, and rests on the topmost part of the Lower Greensand (Folkestone Beds). It consists of angular and subangular bits of flint, Tertiary pebbles, pieces of chert and Kentish Rag, and pebbles of Wealden sandstone, and large lumps of sandstone resembling "Greywethers." It is interstratified in places with beds of coarse sand, and beds of loam are occasionally met with.

Bones or teeth of the following Mammals have been found in the Aylesford gravel:—

Elephas primigenius,	Equus.
Rhinoceros,	

The teeth of the Elephant are very common; and occasionally very fine tusks are found.

The next well-marked terrace on this bank of the Medway occurs on the top of the hill half a mile north-west of Maidstone Gaol, at a height of 200 feet above the river. Its position is shown in fig. 2, p. 451. It consists of angular and subangular bits of flint and chert, with Tertiary pebbles and pebbles of Wealden sandstone: it is distinctly stratified. On the left bank of the Medway, near Maidstone, there is a good deal of gravel, occurring in three or more terraces up to the level of 300 feet above the river*. The gravel exactly resembles that found on the opposite bank, and we need only notice that which occurs at the higher levels. About half a mile east of East Malling Heath, gravel is found at a height of 300 feet above the Medway; it contains pebbles of Wealden sandstone, flints, chert, and Tertiary pebbles, and resembles undoubted river-gravel. At East Malling Heath, at a height of 275 feet above the Medway, there are some beds of brick-earth with a little gravel, which have been proved to be 36 feet thick in places. One of the pits shows a beautifully stratified deposit, which few persons would deny to be of true river origin. This brick-earth probably lies in a "pipe," like those to be described hereafter.

b. *Tributaries of the Medway: River Eden.*—The first tributary of any importance is the River Eden. Sir R. I. Murchison, in his paper "On the Flint Drift of the South-east of England" †, has described some gravel at Hever Lodge, on the left bank of the Eden, and gives a section showing its position. The gravel resembles that of Aylesford, and in appearance and lie seems to be a true river-gravel. Sir Roderick, however, in his paper, will not admit that this

* These terraces, except the highest (of which little now remains), appear, in tracing them down the valley, to fall to a *lower relative level* as compared with the river beneath. The cause of this is not at all clear. Mr. Prestwich (Phil. Trans. 1864, p. 252) has noticed the same fact in the valley of the Waveney. Mr. Bristow informs me he has also observed it in the terraces of gravel in the Thames valley.—W. T.

† Quart. Journ. Geol. Soc. vol. vii. (1851) p. 381.

Fig. 2.

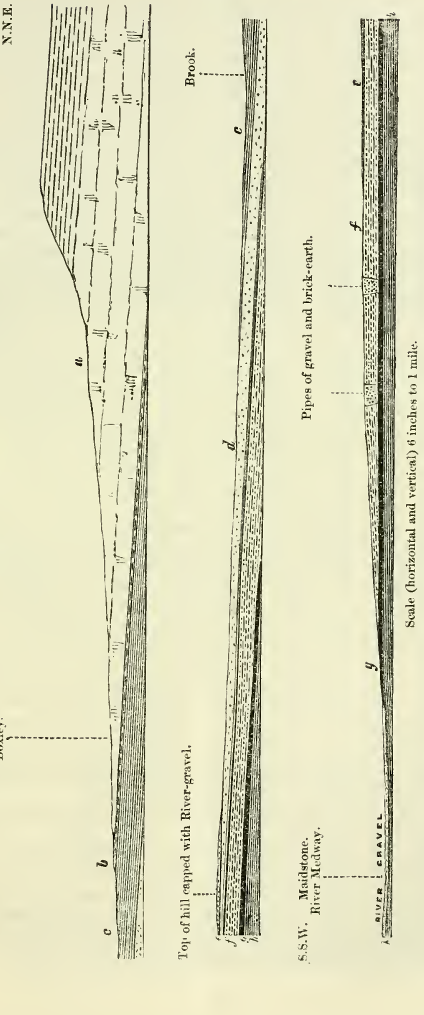


Fig. 2.—*Section from Maidstone to Boxley.*

a. Chalk.
b. Upper Greensand.
c. Gault.
d. Folkestone Beds.
e. Sandgate Beds.
f. Hythe Beds.
g. Atherfield Clay.
h. Weald Clay.

gravel was deposited by any "ancient river following the direction of the present streams," because it contains Chalk-flints which are not found in place until we have crossed the high Greensand escarpment, and at a distance of seven miles. It must be recollected, however, that tributaries of the Eden rise at the Chalk near Titsey and Godstone; and the old gravel found near them is composed, as we are informed by our colleague, Mr. W. Boyd Dawkins, of flints and chert, brought down, no doubt, by the tributary streams. These streams, then, probably furnished the Eden with the flints and Tertiary pebbles * which are now found in its old alluvia. Again, the Plaxtole Brook doubtless helped to furnish the flints and Tertiary pebbles found in the Hadlow gravel. On the eastern side of the Medway basin, in the Weald Clay valley, where there are no streams coming in from the Chalk, flints are very rare, and the river-gravel is almost entirely composed of Wealden pebbles. This fact is in favour of the theory that the flints at Hever and Hadlow were brought down by tributaries coming from the Chalk. Mr. W. Boyd Dawkins, who mapped the gravel at the eastern and western ends of the Medway basin, has arrived at the same conclusion †.

Rivers Beult and Teise.—Deposits of gravel are found along the banks of both these streams, and in the angle formed by the junction of the two streams a considerable spread of gravel is met with. There are four patches of gravel lying at about the same level, (50 or 60 feet above the rivers Beult and Teise), which appear to have been once united, forming a broad plateau. Gravel was no doubt deposited at the junction of the Beult and the Teise when these rivers were at a much higher level and their junction further south-east. As these rivers worked their way to the west and to the north, the spread of gravel increased. The rivers at the same time gradually cut their way down deeper; their old beds were left high and dry, and were at once attacked by the denuding agencies of the atmosphere. Little valleys, some 20 feet deep, have been cut through the gravel and the underlying clay, and all that remains of the broad plateau are the four above-mentioned patches.

Sections of the gravel are seen at Marden and at Wantsuch Green. It consists almost entirely of pebbles of Wealden sandstone; a few quartz-pebbles ‡ also occur, and occasionally a few flints are met with. Sir R. I. Murchison, in his paper just alluded to, mentions the fact that remains of the Mammoth were found in the gravel at Marden §.

* Beds of pebbles are found capping the Chalk escarpment near Godstone, believed by Mr. Prestwich to be unconformable Tertiaries ("On the Thanet Sands," Quart. Journ. Geol. Soc. vol. viii. (1852), p. 256).

† This is also shown by Mr. Prestwich in the map appended to his Memoir in the Phil. Trans. for 1864.

‡ Pebbles of quartz, as big as a hen's egg, are sometimes found on the Weald Clay about Marden and other places, as well as being found in the gravel. Whence these pebbles are derived is somewhat uncertain.

§ I may add here that I found the pointed end of a flint-implement, of the spear-head shape, in a field at Marden: part of the field was on the river-gravel. I also found an oval-shaped flint hatchet on the surface of a field near Maidstone, though at some distance from any existing deposit of river-gravel. Both implements resemble those that have been found in gravel.—C. L. N. F.

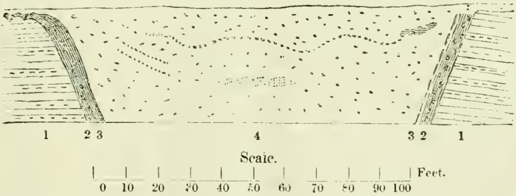
In the foregoing description we have spoken only of those sections especially worthy of notice. It is needless on this occasion to enter more fully into the subject, as the whole area will be more minutely described in a forthcoming Memoir of the Geological Survey.

4. *Pipes of Gravel and Brick-earth.*—Where the gravel and brick-earth rest on the Kentish Rag they are generally let down into "pipes" or "pot-holes," which sometimes attain a very large size. As these pipes not only show the great thickness of the gravel and brick-earth, but also give proof of a considerable lapse of time since the deposition of these old alluvia, we will proceed to describe them in detail. The best sections are seen in some brick-fields to the north of the town of Maidstone. The section (fig. 2, p. 451) will show how the beds occur. The brick-earth is found in long deep pipes, one of which has been proved to go through the entire thickness of the Kentish Rag to the Atherfield Clay beneath. The direction of many of the pipes is a few degrees west of north. They gradually dwindle away and die out at their north and south extremities; but some can be traced for the distance of a quarter of a mile.

The largest pit, which is in Mr. Goodwin's brick-field, is 50 yards broad, and is worked to a depth of 40 feet; it has been dug 10 feet lower, but the running sand which is then met with prevents further working.

The accompanying section (fig. 3) across the large pit in Mr. Goodwin's brick-field will show how the brick-earth lies:—

Fig. 3.—*Section across a Brick-earth pit, Maidstone.*



1. Kentish Rag.
2. Clay with angular and weathered lumps of Rag.
3. Sandgate Beds: fuller's earth interstratified with beds of sand.
4. Brick-earth distinctly stratified. In the lower part of the pit, the strata are contorted.

A little gravel is interstratified with the brick-earth. It contains pebbles of Wealden sandstone, angular and rounded flints, and pieces of chert. Similar pipes are seen in the same brick-field and in another to the south-west; all are characterized by the lining of Sandgate Beds.

On the opposite side of the Medway, about half a mile south of Allington Church, there is a small railroad leading from the river to a Rag quarry. Along the cutting which has been made, as many

as seventeen pipes may be counted, as shown in fig. 4. They vary in width from 6 feet to 50 feet. Some of them in the quarry are seen to be 30 feet deep; and of course as no signs of their ending off are seen, they go down deeper: one has been proved to be at least 50 feet deep.

In the Iguanodon-quarry, belonging to Mr. Bensted, some good examples of small pipes are seen, one of which is shown in fig. 5.

The organic remains found in the brick-earth resemble those obtained from the gravel. Remains of the following Mammalia have been found *:—

Elephas primigenius,
Rhinoceros tichorhinus,
Cervus,
Equus.

The brick-earth † has also been found to contain the following shells, kindly determined by Mr. Etheridge:—

Helix fulva (*Müller*),
—— hispida (?), *Linn.*
Pupa muscorum, *Pfeiffer.*
Succinea oblonga, *Drap.*
Zua subcylindrica, *Linn.*
Pisidium *or* Cyclas.

This *Pisidium* or *Cyclas* was found by our colleague, Mr. T. McK. Hughes.

Pipes similar in character to those of our district are of frequent occurrence in limestone strata. To account for them, two theories have been brought forward. Mr. Trimmer, in numerous papers in the Society's Journal, argued that the pipes had a mechanical origin. Dr. Buckland, Sir Charles Lyell, Mr. Prestwich, Mr. Kirkby, and others have upheld the notion that the pipes were produced by the slow dissolving action of water charged with carbonic acid. This view is now so generally adopted, and is so entirely consistent with observed facts, that it is unnecessary for us to enter very minutely into the matter. We will therefore content ourselves with referring for

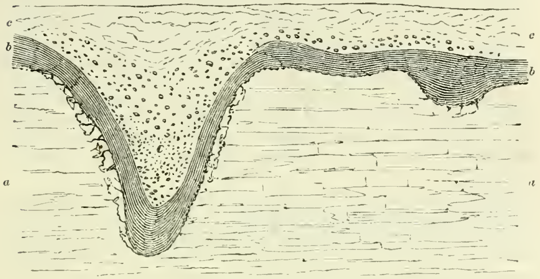
Fig. 4.—*Section of Brick-earth pipes and Kentish Rag, half a mile south of Allington Church.*

* Mr. Bensted ('Geologist' for 1862) mentions *Hippopotamus* as occurring in the brick-earth; and Prof. Owen gives *Hyæna spelæa* (Brit. Fos. Mam. 1846, p. 151).

† See also the paper by Prof. Morris, Mag. Nat. Hist. vol. ix. 1836, p. 593, where lists of fossils are given.

a full account of this subject to Mr. Prestwich's admirable paper "On the Origin of the Sand and Gravel Pipes in the Chalk of the London Tertiary District" *.

Fig. 5.—*Section of "Pipes" in Iguanodon Quarry (May* 1864).



a. Kentish Rag. *b*. Sandgate Beds *c*. Gravel.

In the case of the pipe shown in fig. 5, few persons would hesitate to admit that the following was the mode of its formation:—Gravel was deposited on the surface of the Sandgate Beds, then resting horizontally on the Kentish Rag; afterwards part of the Kentish Rag was dissolved away by the percolation of water charged with carbonic acid, and the Sandgate Beds and gravel sank down to fill the vacant space. In many of the quarries we find every gradation between small pipes and large ones; and if it is admitted that the small pipes were formed in the manner described above, the same mode of formation must be allowed for large ones.

It seems at first not a little remarkable that where beds have been let down in pipes into limestone, they are generally separated from the limestone by a bed of clay. The only exception of which we are aware is in the case of some pipes in the Magnesian Limestone, described in the 'Geologist' for 1860, by Mr. Kirkby, who says (p. 297), "The pipes are found in the limestone beneath the sand beds. I have never noticed them where the sand is absent; and though they are sometimes filled with clay, or a mixture of clay and sand, yet in these instances a thin layer of sand is always the immediate cover of the limestone; nevertheless, the quarrymen assert that pipes have occurred in other parts of the hill where the limestone is immediately covered by the Boulder Clay."

The clayey covering of the Chalk ("clay-with-flints"), and also the clay lining the Chalk pipes, may be the direct result of chemical action upon the chalk; but facts about to be described render it at least probable that a horizontal covering of clay, whether formed by chemical action or actual deposition, may help the formation of pipes.

* Quart. Journ. Geol. Soc. vol. xi. 1855, p. 64.

Dr. Fitton, in his paper "On the Strata below the Chalk" *, describes pipes and furrows in calcareous beds, lined with clay which also caps horizontally the limestone. In these cases the clay is certainly not the result of chemical action upon the subjacent beds, as it forms part of the Purbeck and Portland series. At p. 276, Dr. Fitton figures and describes a pipe in the Portland Beds at Great Hazeley, in which "dark brown clay like fuller's earth" overlies the calcareous beds and passes round the pipes. Speaking about Oxfordshire, Berkshire, &c., Dr. Fitton says (p. 279), "in a great number of the quarries in this part of the country, the ferruginous sands at the upper part (Lower Greensand) are separated from the rubbly stone beneath (Purbeck) by a dark tough clay, 4 to 9 inches thick, which follows the irregularities of the mass below, and coats the bottom of cavities like the 'gulls' of Hazeley" †.

Mr. Conybeare describes similar appearances at the junction of the Kimeridge Clay and Coral Rag ‡.

In most of the cases mentioned by Dr. Fitton, the clay is stated either to consist of, or to contain, "*fuller's earth*." It is worthy of note that the Sandgate Beds, which universally, as far as we know, line the Maidstone pipes, are of this nature.

Mr. Prestwich, in his paper on "Pipes" already alluded to, notices the effect of a bed of clay in the cases of the pipes in the Chalk. He says (p. 79), "As the gravel is generally without any such partially impermeable seam at its base as occurs in the Tertiary sands, the underlying chalk surface seems to have been liable to be attacked by the acidulated waters in a greater number of places, and to present a larger proportion of pipes and indentations than when overlain by the sands," with the clayey band at their base. The effect of the Sandgate Beds is no doubt similar: they hold up the water which sinks through the porous bed above, and thus protect the limestone beds below *in most places*. At those points, however, where the clay is in any way permeable, much water passes down, and chemical action goes on rapidly. The clay therefore serves to concentrate at particular points or along particular lines that action which, were no clay present, would be distributed pretty equally over the whole area. Here we may add that, in the case of the harder limestones, Mr. Prestwich suggests (p. 80) that the pipes are likely to have resulted from the water-wear "being directed into given channels by pre-existing cracks or fissures;" he adds, "some gravel-pipes at Maidstone afford excellent illustrations of such results." The marked parallelism of the long pipes at Maidstone is an argument in favour of their having been originally started along joints or fissures.

Mammalian Remains at Boughton.—In the year 1827 Mr. Braddick found some Mammalian bones in what appear to have been small

* Trans. Geol. Soc. 2nd series, vol. iv. 1836, p. 275 *et seq.*

† These pipes are also noticed by Mr. Hull, 'Mem. Geol. Survey,' Sheet 13, p. 11 (1861).

‡ 'Outlines of the Geology of England and Wales,' p. 189 (foot-note). 1822.

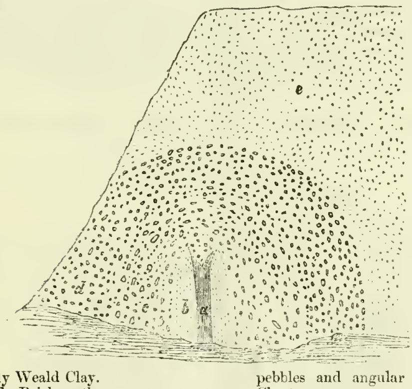
pipes in the Ragstone at Boughton, near Maidstone. Dr. Fitton * describes them as "irregular fissures or cavities, approaching to a conical figure called 'vents' by the workmen, ... filled with loose rubbly stone and sandy clay." Sir R. I. Murchison, who visited the place with Dr. Buckland, says †, "the bones had been preserved under a copious accumulation of impervious loam and clay." Prof. Morris has also noticed these remains ‡. Mr. W. Boyd Dawkins has favoured us with the following list of the bones found at Boughton, and deposited in the Society's Museum, and described as from a cavern :—

Hyæna, mentioned by all the authors identified as *H. spelæa* by Mr. Dawkins.

Wolf. Fox. Water-rat	Prof. Morris.	Young Rodent's jaw. *Cervus elaphus.* *Rhinoceros tichorhinus?* *Equus.*	Mr. Dawkins.

5. *Disturbances in the Gravel.*—Attention has frequently been drawn to the occurrence of faults and contortions in superficial de-

Fig. 6.—*Section of a Brick-earth pit, near Hadlow.*



a. Shaly Weald Clay.
b. Sandy Brick-earth.
c. Gravel, consisting chiefly of pebbles of Wealden sandstone, but containing also numerous Tertiary pebbles and angular pieces of Chert.
d. Fine gravel and coarse sand, with a little coarse gravel.
e. Brick-earth.

posits. Many instances have been quoted by Sir Charles Lyell §, Mr. Trimmer ‖, and more recently by our colleague Mr. Green ¶.

* Trans. Geol. Soc. 2nd series, vol. iv. (1836), p. 132.

† Quart. Journ. Geol. Soc. vol. vii. (1851), p. 383.

‡ Mag. Nat. Hist. vol. ix. (1836), p. 595.

§ Phil. Mag. New Series, vol. xvi. 1840, p. 345, and Proc. Geol. Soc. vol. iii. 1840, p. 171 ; also 'Antiquity of Man,' 1863, chapts. 12. and 17.

‖ Quart. Journ. Geol. Soc. vol. vii. (1851), pp. 22-30.

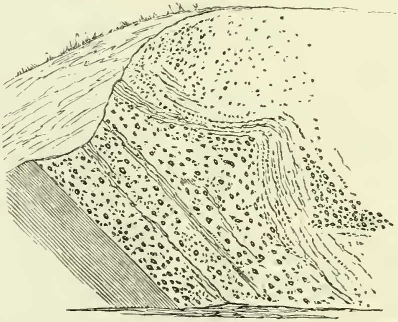
¶ Mem. Geol. Survey, Sheet 45 (1864), p. 55.

Disturbances in true river-deposits are described by Mr. Godwin-Austen * as occurring in the gravel of the Wey valley. In one section figured by Mr. Godwin-Austen, gravel is seen *faulted* against Neocomian clay. Mr. Prestwich † has also figured and described disturbances in the river-gravel of the Somme: they are stated to occur chiefly in the higher gravels. Mr. Trimmer, Sir Charles Lyell, and Mr. Prestwich look to ice as the cause of these phenomena.

Disturbed gravel has occasionally been met with in the basin of the Medway. At a brick-earth pit, near Hadlow (marked *Pottery* on the Ordnance Map), some gravel beds have been bent into a sharp anticlinal, enclosing in the centre a little of the Weald Clay, which underlies the gravel. The sketch on the last page (fig. 6) will give a better idea of the section than any verbal description. One way of accounting for the disturbance is by supposing that the gravel was bent up by the grounding of some large mass of ice. This explanation is in accordance with the theory that the climate, during the deposition of the older gravels, was colder than at present.

In September 1864 a considerable section of loam and gravel was open at Leney's Brewery, Wateringbury. The gravel resting on Atherfield and Weald Clay was seen distinctly dipping 25° to 30° to the N.E. This appearance was certainly not due to false-

Fig. 7.—*Section in a Gravel-pit north of Maidstone Gaol.*



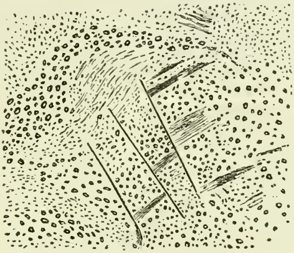
bedding, as all the beds, both fine and coarse, showed it equally well. The gravel, therefore, must have been disturbed since its deposition.

* Quart. Journ. Geol. Soc. vol. vii. (1851), p. 285.
† Phil. Trans. vol. cl. (1860), p. 299, and vol. cliv. (1864), p. 269.

In the gravel already described as occurring half a mile north of Maidstone Gaol, some of the deposit has plainly been disturbed since its deposition (fig. 7). The gravel is resting on Folkestone Beds: both dip at an angle of about 40°. The pebbles have their longer axes in the same direction, while the finest gravel and sand dip just as much as the coarser kinds. Here it seems plain that the gravel was deposited on horizontal Folkestone Beds, and that the whole has subsequently been disturbed.

It does not seem probable that *ice* should have produced this result; it is more likely that some of the underlying Rag has been dissolved away, causing a subsidence of the overlying beds. Fig. 8, from another part of the same pit, shows some small faults produced by the disturbance.

Fig. 8.—*Section in another part of the same pit as Fig. 7.*



Disturbed Gravel at Preston Quarry, Aylesford.—Mr. Bensted, of Maidstone, has published * an account of the strata at Preston Quarry. He describes and figures a sharp anticlinal affecting both the Greensand beds and the overlying gravel. Sir R. I. Murchison, in his paper "On the Flint Drift of the South-east of England" †, also alludes to this section. Mr. Bensted considers certain perforations by marine shells in the topmost bed of Rag to be of recent origin. A careful examination, however, will prove, we think, that the bed in which Mr. Bensted has found perforations is overlain by Sandgate Beds and Folkestone Beds; therefore the perforations must belong to the Greensand period. It certainly seems, however, that the gravel has been disturbed since its deposition. May not this be due to a dissolving away of the Rag, producing a subsidence in two places, which has caused the strata to dip down on both sides of the quarry in the manner described by Mr. Bensted?

* 'Geologist,' 1862, p. 450.
† Quart. Journ. Geol. Soc. vol. vii. (1851), p. 383 (foot-note).

Part II. On the Denudation of the Weald.

Having now described the chief phenomena connected with the superficial beds of the Medway valley, we will pass on to consider the light which they throw upon the much-disputed question of the "Denudation of the Weald." We think it will be conclusively shown that "rain and rivers" have been the main agents in producing the present form of the ground.

We propose to treat the subject in the following manner:—

a. Short sketch of previous theories, with objections to the theory of fracture, and to the marine theory.

1. Theory of Fracture. 2. Marine theory.

β. Bearing of the river-gravel on the question.

γ. On the mode of deposition of beds of gravel and loam, and on the action of streams and rivers in modifying their channels.

δ. On the origin of escarpments.

a. Short Sketch of previous Theories, with Objections to the Theory of Fracture and to the Marine Theory.—In the Introduction prefixed to Conybeare and Phillips's 'Outlines' *, Mr. Conybeare gives an account of the combination of longitudinal and transverse valleys, or those running respectively along and across the strike, of which the Weald is an excellent example. He attributes their formation to running water; but adds, "it is easy to show that the phenomena attendant on valleys are very commonly of such a nature that to believe them to have been formed by their actual rivers, however long their action may have endured, involves the most direct physical impossibilities." Mr. Conybeare also points out (p. 145) that, if the tranverse valleys were filled up, the whole drainage of the country would pass out by Romney Marsh and Pevensey Level.

Mr. Scrope †, in 1825, in speaking of the results of volcanic action, alludes to the Weald as the result of upheaval, during which "a longitudinal crack opened across the beds parallel to the axis of elevation. The chalk, resting on beds of clayey marl, slipped away on either side from the axis, leaving bare the lower strata of greensand. Again, the partial subsidence of this formation upon the slippery beds of the Weald Clay disclosed in turn the iron-sand, which forms the visible axis of this ridge." Such valleys the author proposed to call "valleys of *elevation and subsidence*, or *anticlinal* valleys" ‡. He considers that they may have been "subsequently enlarged and otherwise modified; and many others, perhaps indeed a far greater number, wholly and entirely excavated by the slow but constant and powerful action of the same causes which are still continually in force; amongst which the fall of water from the sky, and its abrasive power as it flows over the surface of the land from a higher to a lower level, is the principal" (p. 214).

* 'Outlines of the Geology of England and Wales,' 1822, p. xxiii.

† 'Considerations on Volcanos,' chap. 10, p. 213.

‡ Dr. Buckland, in 1825, proposed to call the Weald and similar valleys, "valleys of elevation" (Trans. Geol. Soc. 2nd series, vol. ii. p. 119).

Mr. Martin *, in a series of publications extending over thirty years, taught that the Weald was denuded "by the joint operation of earthquakes and diluvial currents." The results of these violent actions he found in the various "drifts" with which the country is in places covered.

Mr. Hopkins †, in 1841, submitted a paper to the Society, "On the Structure of the Weald," in which some of the chief lines of disturbance were traced, and their supposed bearing on the physical geography of the Weald pointed out; also the connexion between transverse and longitudinal fractures. We shall allude more fully to this subject immediately.

Sir Charles Lyell ‡, in 1833, brought forward the marine theory of denudation, which, with little alteration, has held its place until the present time.

Sir Roderick Murchison §, in 1851, published his paper "On the Flint Drift of the south-east of England." He described with great care the drift of the Wealden area generally, and considered it to be owing to great rushes of water which mingled the débris of the various beds into the present drift deposits, burying the remains of Mammalia. This took place when "the country had to a large extent assumed its present form."

Col. Greenwood ‖, in 1857, published his views upon the question of denudation with special reference to the Weald. He maintained that the valleys were wholly formed by "rain and rivers."

In 1862 Mr. Jukes ¶ read before the Society a paper on the river-valleys of the South of Ireland, in which he advocated the theory that these valleys were formed by atmospheric denudation. In a postscript (p. 400) he adds, "My acquaintance with the Weald of Kent is too superficial to allow me to express an opinion; but perhaps I may venture to ask the question, whether the Chalk, when once bared by marine denudation, which perhaps removed it entirely from the centre of the district, has not been largely dissolved by atmospheric action; and whether the lateral river-valleys that now escape through ravines traversing the ruined walls of Chalk that surround the Weald may not be the expression of the former river-valleys that began to run down the slopes of the Chalk from the then-dominant ridge that first appeared as dry land during or after the Eocene period?"

Prof. Ramsay, in 1863, while admitting that considerable ma-

* 'Geological Memoir on Western Sussex,' 1828; Phil. Mag. (1829), p. 111; Phil. Mag. 4th series, vol. ii. 1851 (pp. 44 *et seq.*), containing a paper read before the Geol. Soc. in 1840; Phil. Mag. (1854), p. 166; Phil. Mag. (1856), p. 447; Quart. Journ. Geol. Soc. vol. xii. (1856), p. 134.

† Trans. Geol. Soc. 2nd series, vol. vii. (1845) (read in 1841).

‡ 'Principles of Geology,' 1st edit. vol. iii. (1833), chap. 21.

§ Quart. Journ. Geol. Soc. vol. vii. p. 349.

‖ 'Rain and Rivers; or Hutton and Playfair against Lyell and all Comers,' 1857.

¶ Quart. Journ. Geol. Soc. vol. xviii. (1862), p. 378. See also a letter by Mr. Jukes, in 'The Reader' for 12th March 1864.

rine denudation may have taken place, says * that the Weald was denuded "probably to a great extent also by the influence of atmospheric agencies." In 1864 he further explained † his views, and gave many arguments against the marine theory.

1. *Theory of Fracture.*—Mr. Hopkins, and other writers on this subject, dwell much upon the longitudinal dislocations of the Weald, and draw the inference that the well-known longitudinal valleys are the direct results of these dislocations. But, if this be so, the valleys and the faults ought to coincide, not only in direction, but absolutely. This they rarely or never do.

The longitudinal valleys run along the outcrop of the softer beds, or those most easily eroded. This of itself is some evidence of their formation by erosion. But the strike of the beds of any area necessarily corresponds in direction with its lines of disturbance, being alike due to elevatory forces acting from beneath. Hence we see that the strike and the faults are effects of the same cause; while the longitudinal valleys are determined by the strike alone, and may be seen to be so in districts where faults are altogether absent.

Against Mr. Hopkins's mathemathical deductions we neither presume nor wish to contend. It is quite certain that longitudinal disturbances have taken place, and it is certainly possible that transverse fissures may have been formed which gave the original direction to the rivers which now run through deeply eroded valleys. Such dislocations, however, must have been mere fissures, and nothing more. There was no possibility of the beds slipping away on either side, nor has any vertical displacement taken place. Therefore the transverse valleys are still "valleys of denudation." Moreover, it is somewhat surprising that the Geological Survey has been unable to find any very important dislocations in any other parts of the Chalk escarpment. The Gault and Greensand lines have been drawn with care, but no marked disturbances are known; nor, as Mr. Hopkins admits, is there any *proof* that dislocations of any kind occur even in the transverse valleys themselves.

2. *Marine Theory.*—The view held by many geologists upon the denudation of the Weald is that, during a long course of time, the waves of the sea have formed the long lines of escarpment passing round the Weald, which are likened to sea-cliffs, such as are now being formed by the action of the sea on the Chalk of Kent and Sussex.

We think the commonly received marine theory untenable for the following reasons:—

(1.) The foot of the Chalk escarpment ‡, and also that of the Lower Greensand, are not at the same level all round the Weald, as every sea-cliff must necessarily be. This inequality of level can hardly be explained by unequal elevations during the last rise of

* 'Physical Geology and Geography of Great Britain,' 1st edit. 1863, p. 64.

† *Op. cit.* 2nd edit. 1864, p. 75.

‡ See Ramsay, *op. cit.* 2nd edit. p. 77.

the land, as the lowest parts are at the river-gorges. This would necessarily be the case if these transverse valleys were cut down by running water, as hereafter described.

(2.) The escarpments follow only the *strike of the beds* *, changing their direction as the strike changes. The British islands, from the number of formations exposed, and their great extent of coast, should furnish some examples of long lines of cliffs following the outcrop of beds, if any ever occur †. But we find, on the contrary, that the sea cuts across all formations alike, quite independently of the strike. It sometimes forms bays and indentations where the strata are soft and easily worn away, but never runs up the country along the outcrop of the beds.

(3.) We never find accumulations of shingle or any other marine deposit at the foot of the escarpments. Sir Roderick Murchison has used this argument against the marine theory. In his paper before alluded to, he says (p. 393), "There is not a single rounded pebble along the lower edges of any of the escarpments that flank the central Wealden; still less does the tract contain any fragments of marine shells; whilst by far the greater part of the detritus is just that which must have resulted from an action which left the shattered débris in positions and conditions which no ordinary sea could have done." "Again, all the fossils found inland are terrestrial."

The gravel at Barcombe, cited by Sir Charles Lyell ‡ as an example of marine drift, is undoubtedly a river-gravel of the Ouse. It occurs near the junction of two streams, and contains Wealden pebbles. In this gravel Mammalian remains have been found §.

Sir Charles Lyell, however, does not seem now to lay much stress on the gravel at Barcombe as being proof of marine action, as he omits any mention of it in his last edition. He also suggests || that marine deposits may have existed, and have since been swept away by atmospheric denudation, without conceding a very considerable power to atmospheric agencies; but as we shall show that "rain and rivers" have effected a very great amount of denudation, there can be no reason, in the absence of positive evidence, for appealing to the action of the sea for the formation of the escarpments, especially as the other objections to the marine theory which we cite still hold good.

(4.) Prof. Ramsay has well pointed out that, if the Weald were now submerged so as to convert the escarpments into cliffs, we should have an arrangement of sea and land in which denudation could act but very feebly. There would be a central group of islands surrounded

* See Rev. O. Fisher "On the Denudation of Soft Strata," Quart. Journ. Geol. Soc. vol. xviii. (1861), p. 3.

† Mr. F. Drew, who mapped a large part of Kent, Surrey, and Sussex, had remarked these facts, and in 1861, if not earlier, had rejected the theory that the Chalk and Greensand escarpments are due to marine denudation.—C. L. N. F.

‡ 'Manual of Elementary Geology,' 5th edit. 1855, p. 287.

§ Mr. Godwin-Austen, Quart. Journ. Geol. Soc. vol. vii. (1851), p. 288.

|| 'Elements of Geology,' 6th edit. 1865, p. 372.

by a strip of water in the Weald Clay valley, then a long ridge of Greensand country; beyond this a second strip of water washing the foot of the Chalk escarpment. "This form of ground would certainly be peculiar, and ill-adapted for the beating of a powerful surf, so as to produce *on one side only* the cliffy escarpment that forms the inner edge of the oval of Chalk"*.

β. Bearing of the River-gravel on the question.—We have endeavoured to show that there are many objections both to the "fracture theory," and to the "marine theory," and we will now proceed to discuss the arguments in favour of the "atmospheric theory" which may be derived from an examination of the superficial deposits, described in the first part of our paper.

We have shown that deposits of river-gravel occur at various heights, sometimes even 300 feet, above the level of the Medway. All this gravel we consider as having been deposited by the River Medway, when its bed was at a much higher level†, and the following are the reasons for this supposition. No one would hesitate to say that the Aylesford gravel is a former bed of the Medway, or, in other words, that the Medway once flowed 40 feet above its present level. When we find similar gravel and brick-earth of river origin, and containing similar fossils, gradually creeping up the hills, we find that we cannot stop at 40 feet, and we are constrained to admit that the Medway flowed at 100, 200, and even 300 feet above its present level, *and in the same direction as at present*; for the river-gravel lying on the Lower Greensand and Gault contains pebbles of Wealden sandstone which must have been brought from areas south of the Greensand escarpment. As the gravel is found at all levels from the 300 feet to the present level of the Medway, we must suppose that the river deepened its bed gradually, and that since the Medway flowed at the 300-feet level no agents, except rain and rivers (and possibly river-ice), can have been working at the denudation of the rocks contained within the basin of the Medway. The next question is, What is the amount of denudation that has been effected since the Medway flowed at the 300-feet level at East Malling? The area shaded on the Map (fig. 9) represents roughly‡ what part of the Medway basin *south* of East Malling is below the 300-feet level. When the Medway was depositing the East Malling gravel, of course all this area must have been above the 300-feet level. Therefore, since the Medway ran at the 300-feet level at East Malling all this area has been denuded. When we add that a large part of this area is 200 and even 250 feet below the gravel at East Malling, the vast amount of the denudation will be perceived.

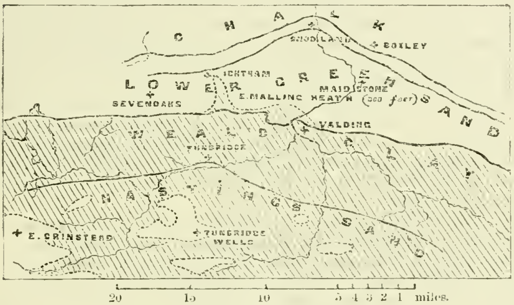
* Ramsay, 'Physical Geology and Geography of Great Britain,' 2nd edit. p. 79.

† Relatively to the strata it was flowing over, though not necessarily higher above the sea-level than it is at present; for, if the river worked its way downwards as fast as the Wealden area was raised upwards, no alteration of its position with regard to the sea-level would take place.

‡ Until the New Ordnance Survey of Kent is completed, it will be impossible to show *exactly* how much of the country is below the 300-feet level; but a rough map is sufficient for our purpose.

And all this denudation has been due to the action of rain and rivers; for we have shown that the Medway deepened its valley gradually; and not only are there no traces of marine action, but had the sea had access since the gravel was deposited, surely it would have swept away such loose and incoherent deposits. If rain and rivers could do so much, if they could cut out a valley 250 feet deep and seven miles broad, surely we may allow that by giving them more time they could scoop out valleys 500 feet deep; in other words, that, making every allowance for slight superficial inequalities produced by marine denudation, all existing inequalities in the basin of the Medway, including the Greensand escarpment and the Chalk escarpment, are entirely due to atmospheric denudation, that is to say, to the action of rain and rivers*. If this holds good for the basin of the

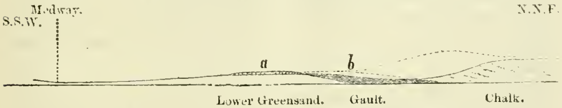
Fig. 9.—*Map of the Basin of the Medway.*



The area shaded shows that part south of East Malling Heath which is below the 300-feet level.

Medway, it may be applied to the whole of the Wealden area. The reason why we have no traces of river-action at the higher levels is that in the long lapse of time these old alluvia have themselves been removed by subaërial denudation.

Fig. 10.—*General Section from Maidstone to beyond Boxley.*



a. Gravel. *b*. Gault Valley.

It is not only the gravel at East Malling that gives proof of vast denudation. Fig. 10 (see also fig. 2) shows the position of the river-

* The Wealden district does not appear to have been under water at all during the Glacial period. Of course throughout this period frost and land-ice must have had an immense effect in wearing down the surface of the country.

gravel between Boxley and Maidstone. It is clear from the position of the gravel at *a* that the Gault valley (*b*) could not have existed at the time of the deposition of the gravel; for when the bed of the Medway was at *a* this must have been the lowest ground of the neighbourhood. Since the deposition of the gravel at *a*, the Gault valley has been eaten out to a depth of 120 feet, and breadth of $1\frac{1}{4}$ mile, and the main Medway valley to a depth of 200 feet, and breadth of two miles. But this is not all; for when gravel was deposited at *a*, the sides of the valley very likely began to rise a little to the east of *a*, as shown by the dotted line; the place of the hill is now occupied by a valley, and what was the bottom of a valley now caps the top of a hill.

The gravel at Marden is another interesting case. This gravel lies about 50 feet above the level of the Teise, and is surrounded on nearly all sides, in some directions for miles, by lower ground. As before, this gravel, which once occupied the bottom of a valley, now forms the tops of hills. These cases (though on a much smaller scale) are exactly similar to that of the basalt-capped hills of the neighbourhood of Clermont, so well described by Mr. Scrope*. Both the lava and the gravel were once in the very bottom of the valleys, whilst now they cap the hill-tops. The denudation implied by this fact is very great; for not only must everything below the level of the present gravel-plateau have been denuded since the deposition of the gravel, but also the very walls of the valley which confined the river at the time of the deposition of the gravel must themselves have been washed away.

γ. *On the Mode of Deposition of Beds of Gravel and Loam, and on the Action of Streams and Rivers in modifying their Channels.*— Before proceeding to the discussion of the origin of escarpments, it may be well to say a few words on the mode of deposition of beds of gravel and loam, and on the action of streams and rivers in modifying their channels.

Gravel occurs and is now being formed in the bed of the present river Medway. It probably underlies the modern alluvium in most places, usually rising from beneath it to join the old river-gravels at the edge of the modern alluvium. Gravel is being constantly brought down by the river, but chiefly of course when the rush of water is greatest; and, as a rule, it is deposited only in the river-bed. No doubt during floods there will be exceptions; but even then only the finer gravel will be swept over the banks, and that will quickly come to rest, while the finer loam will remain much longer in suspension.

During dry weather, or such times as the river is confined within its banks, no permanent deposit of loam will be formed. At times the river may run comparatively clear, the matter held in suspension being small. Of the little it contains, the larger portion will be carried out to sea; some may settle down in sheltered portions

* Mr. Scrope (Volcanos of Central France, 2nd edit. 1858, p. 203) speaks of basaltic lava occurring 1500 feet "above the water-channels of the proximate valleys."

along its course, but these deposits will generally be swept away by the next rush of water; occasionally they are preserved, as proved by lenticular beds of sand and loam interstratified with gravel.

During floods much matter is carried down in suspension by the water. This is deposited by the flood-waters, when, having overflowed their river-banks, their velocity is lost or diminished.

Rivers are constantly changing their courses. This is accomplished by the undermining of one bank, accompanied by a gradual silting-up of the channel on the opposite side. A river may in this way, if the land continues stationary, travel many times across its plain, rearranging and depositing gravel as it goes*. It is interesting to notice that a river, in undermining its banks in the way just described, lays bare gravel deposited long before, and now mixes this with other gravel that it has just brought down. Thus fossils of very different ages (as measured in years) *may be* found imbedded together.

It is also important to notice that the width of an alluvial plain does not depend entirely upon the size of its river, as is frequently assumed in reasoning upon old river-alluvia. This is well shown in our area; and from the description already given (p. 446), it will be seen that the alluvial flat, like the general valley, is broader where passing over the softer beds.

It is manifest too that when the river is not deepening its channel the valley must be growing broader, because rain running down the hill-sides washes down material which, when it reaches the river, is carried away. The river, too, often reaches the edges of the alluvial plain, and then undermines the rocks that bound it. Each successive flood adds to the thickness of the alluvial deposits, and these gradually creep up the sides of the valley. Thus, if no elevation occurs, the alluvial plain will gradually widen. This effect will be produced much more rapidly if a *depression* occurs; the river will then raise its bed and thicken the deposit of gravel.

The greatest floods occur now a little way within the Chalk escarpment near Snodland, and just within the Lower Greensand escarpment at Yalding, which has been called the "Sink of Kent." At both these places the drainage of a considerable area is concentrated into a narrow gorge, and this is doubtless the cause of the floods. *It is probable that these cases are analogous to the former condition of the country, when the great deposits of brick-earth at Maidstone and Hadlow were formed.* Thus, when the brick-earth, now let into pipes on both sides of the river at Maidstone, was deposited, the Chalk escarpment was further south than at present, and the gorge was much nearer the brick-earth beds. The proximity of Maidstone to the then-existing gorge may very likely be the reason why the old alluvium was subject to those often-repeated floods, which have produced the thick deposits of brick-earth which now remain. A similar explanation may be offered to account for the

* See Fergusson "On the Delta of the Ganges," Quart. Journ. Geol. Soc. vol. xix., 1863, p. 321.

Figs. 11–14.—*Plans and Sections illustrating the formation of Escarpments.*

Fig. 11.

Fig. 12.

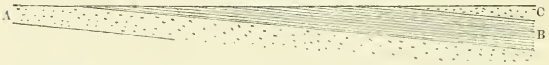


Fig. 13.

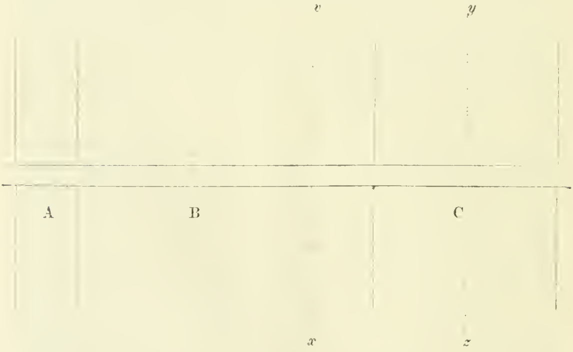
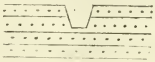


Fig. 14.—*Section along the line* y z.



Figs. 15–18.—*Plans and Sections illustrating the formation of Escarpments.*

Fig. 15.—*Section along the line* v x.

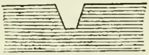


Fig. 16.—*Section along the line* y z.

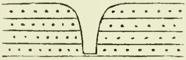
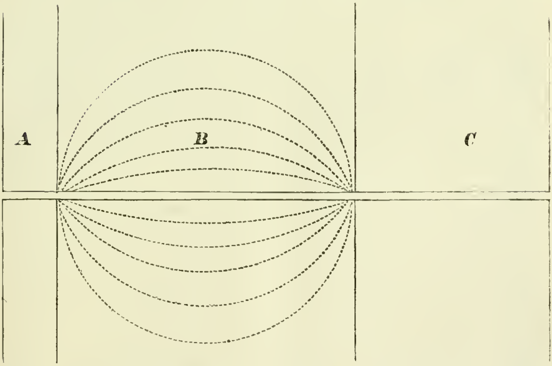


Fig. 17.—*Section along the line* v x.

Fig. 18.



great spread of brick-earth round Hadlow. The brick-earth there is not let into pipes, because it rests on clay.

The occurrence of great floods, as suggested by Mr. Prestwich*, may also be due to the probable low winter-temperature during the deposition of the higher gravels. The effect of a low winter-tem-

* Proc. Royal Soc. for March 1862, p. 47; Phil. Trans. vol. cliv. 1864, p. 290.

perature would be the storing up of snow and ice, the sudden melting of which in the spring would bring about floods.

We have thus far been speaking of the rivers when the land is stationary or sinking. If, however, an elevation takes place, the river will commence deepening its channel. The elevatory action may be so slow as to allow the river to travel all over its alluvial plain, reducing all alike to a new level; but more commonly "terraces" of the old alluvium will be left, which, unless completely removed by atmospheric action, will remain to show the former position of the river. This process we conceive to have been going on during a long period of time in the Medway valley, the gravel at the 300-feet level being the oldest river-bed remaining; between which and the nearest point of the Medway there is no higher ground intervening.

δ. *On the Origin of Escarpments.*—In treating this subject we will first take a hypothetical case, and then apply the principles there explained to the area under consideration*.

Let fig. 11 represent in plan, and fig. 12 in section, three beds, A, B, and C,—A and C being sandstone, and B being clay; and let us suppose the plane formed by the denuded edges of the beds to slope down in the direction from A to C; let rain fall on this sloping surface, slight inequalities of the ground will make the rain flow into a number of small rivulets, and, as the principal slope is at right angles to the line of strike, the rivulets will take the same general direction, and begin cutting out channels or small transverse valleys. In plan, the channel would be shown as in fig. 13. If we had nothing but sandstone of uniform hardness, the stream would merely cut itself a gorge, the breadth of which would be the same all along. When we come to rocks of different hardness, however, the case is otherwise. The stratum B, being of clay, will suffer much more from atmospheric denudation at the sides of the gorge than the strata A and C. Each shower of rain, each frost, will do its part in degrading the soft clayey walls of the valley; slips, too, may come to our aid, and the transverse stream will carry off the débris and rain-wash. In this manner the valley will be widened where it passes through the bed B. Figs. 14 and 15 will show sections, along the lines *v x* and *y z*, through the sandstone bed and through the clay bed, before the atmospheric agencies have had much action. Figs. 16 and 17 show similar sections through the two beds, after the denuding powers of the atmosphere have produced some effect. The valley on the clayey strata is widened considerably, whilst the walls of the valley where formed by sandstone have scarcely suffered any change. The result of atmospheric action will be that the walls of the valley will get less and less steep where they are formed by the bed B. A sort of amphitheatre will be formed on each

* We would here again refer to the excellent paper by Mr. Jukes, in which the connexion between longitudinal and transverse valleys was first clearly explained, "On the River Valleys of the South of Ireland," Quart. Journ. Geol. Soc. vol. xviii. 1862, p. 378. See also Mr. Geikie's 'Scenery and Geology of Scotland,' 1865, p. 138.

side of the transverse valley, and these amphitheatres will extend themselves backwards along the strike, as shown by the dotted lines, fig. 18. Soon we shall have sufficient area to support a brook, and thus we shall get two brooks at right angles to the transverse valley, fig. 19. Fig. 20 shows a section from *r* to *s*, and fig. 21 a section from *p* to *q*. Of course, rain running down the slope, *b a*, will gradually wear off the face of the clay, and undermine the sandstone. In time the end of the sandstone, *b*, will succumb to the never-ceasing atmospheric agencies, and an escarpment will begin to be formed. An escarpment will be formed, and not an even slope, on account of the difference in hardness between the clay and the sandstone; and the latter will project, because it will suffer less from the action of rain than the clay. In the case we have assumed, there is another element to be taken into consideration, besides hardness. The sandstone will soak in a great deal of the rain that falls upon it, whilst every drop that falls upon the clay will produce a certain amount of mechanical erosion. However, where there is a steep slope on the sandstone the rain may produce considerable mechanical erosion, and the face of the escarpment will gradually be worn back, as shown by figs. 22 and 23, The sandstone-plain will also suffer to a certain extent, and its general level will be lowered slightly; but it will suffer much less than the face of the escarpment, as its slope is but small.

The rate at which the escarpment is worn back will depend on the rate at which the river deepens its valley. It must not be inferred from this that the escarpment would not go on wearing its way back, if the stream merely performed the office of carrying the rainwash down into the transverse valley. The escarpment would continue to wear its way back, but the difference in level and, consequently, the slope between the edge of the escarpment and the bottom of the valley would constantly be getting less; if the level of the land remained stationary, the amount of rainwash would get less and less, and in time the slope would get so small that rainwash would not be carried down, and the formation of the escarpment would cease. If, however, the stream at *a* has an excavating power, which enables it to preserve a certain slope between itself and the escarpment, then the wearing back will always go on. The excavating power of the stream in the longitudinal valley will depend on that of the transverse valley; and if the sea-level remains constant, the transverse stream will go on deepening its bed and lessening its excavating power, until at last it ceases to have any at all. A slight elevation of the land would once more give the transverse stream an excavating power, which in time would be communicated to the longitudinal streams.

From what we have said it will be seen that we consider escarpments to be due to the difference of waste of hard and soft rocks under atmospheric denudation. When once a transverse valley has been formed, longitudinal valleys will be formed along the strike of the soft beds, and escarpments will be formed by the hard beds on the side on which the beds dip away from the valley, as in fig. 23.

Figs. 19–23.—*Plans and Sections illustrating the formation of Escarpments.*

Fig. 19.

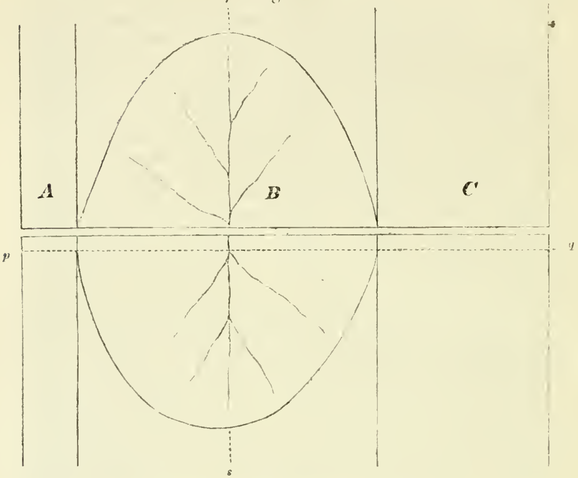


Fig. 20.

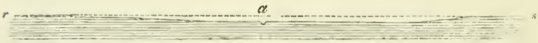


Fig. 21.

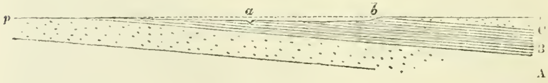


Fig. 22.

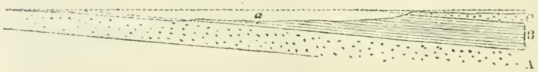


Fig. 23.

In the case of the Weald we have a long escarpment formed by the Chalk, and another by the Lower Greensand. We have already spoken of the many objections to their marine origin. There remains then only pure atmospheric denudation to account for these escarpments; and as we have what we consider *proof* that the Medway has deepened its valley 300 feet, we are not afraid of ascribing great effects to such a cause as atmospheric denudation. It must not be inferred, however, that we consider the escarpments to be *river-cliffs*. The longitudinal streams, though running parallel to these escarpments, do not run directly below them, but often, as with the Medway itself, at a considerable distance. No river-gravel in this area is ever found on *the face* of the escarpment; nor can we discover thereon any traces whatever of river-action. We have no reason then to ascribe them to the immediate action of the streams.

The manner in which we consider the denudation of the Weald to have taken place is as follows. After a large portion of the Tertiary and Upper Cretaceous strata, with some of the Lower Cretaceous beds, had been removed by marine denudation*, a comparatively plane surface was formed, which gradually appeared above water; probably the centre of the Wealden area rose out first, forming an island, and then as the land rose a spread of country was formed sloping down to the north and south from an east and west ridge. The central ridge determined the flow of the water that fell upon the area, streams began to flow to the north and to the south, and in this manner the transverse valleys of the Wey, Mole, Darent, Stour, Cuckmere, Ouse, Adur, and Arun were first started. At the same time the longitudinal valleys along the strike were formed, on account of the difference in hardness between the various rocks. The moderately *hard porous* Chalk has suffered less than the *soft impervious* Gault, and the *hard porous* Lower Greensand has been less denuded than the *soft impervious* Weald Clay. As we are dealing with limestone beds, we must take into consideration the chemical action of the rain charged with carbonic acid. The top of the Chalk and Kentish Rag certainly suffer from this action, and their general level is gradually being lowered. The mechanical atmospheric denudation, however, exceeds the chemical denudation, and, in spite of the general lowering of the Chalk and Kentish Rag, they still form escarpments.

Conclusion.

In conclusion, we will revert to the main points discussed in this paper.

After describing the gravel of the Medway valley, we have endeavoured to prove that an old river-gravel of the Medway occurs 300 feet above its present level. We have then shown that, if this fact be admitted, it follows that so large a denudation has been effected by rain and rivers that there can be but little difficulty in

* The term "plain of marine denudation" was first used by Prof. Ramsay (see Brit. Ass. Rep. 1847, Trans. Sects. p. 66).

supposing the present form of the ground in the Weald to have been produced entirely by these agents.

With regard to the time which has elapsed since this denudation commenced, nothing can as yet be said with certainty save this, that the plain of marine denudation was formed *after the deposition of the Eocene beds*, and that, therefore, the present valleys of the Weald have been formed since that period. Should the doubtful beds occurring at intervals along the top of the North Downs turn out to be Crag*, as believed by some geologists, "then," to quote again Prof. Ramsay †, "the bay-like denudation of the Weald has probably entirely taken place since that epoch; implying another lapse of time so long that, by natural processes alone, in rough terms, half the animal species in the world have disappeared, and been as slowly replaced by others. This may mean little to those who still believe in the sudden extinction of whole races of life; but to me it signifies a period analogous to the distance of a half-resolved nebula—so vast that if it were possible to express it in figures the mind would refuse to grasp its immensity."

* Prestwich, 'Quart. Journ. Geol. Soc.' vol. xiv. 1858, p. 322. Sir Charles Lyell (Elements of Geology, 6th edit. 1865, pp. 232 and 368) considers these beds to be Upper Miocene. In the last edition of Mr. Greenough's Map (1865) they are coloured "Crag."

† 'Physical Geology and Geography of Great Britain,' 2nd edit. p. 84.

ERRATA ET CORRIGENDA.

Page 445, line 4, *for* "grounds lopes" *read* "ground slopes."

,, 450, line 2 from bottom, *after* valley *insert* in Essex.

Map.—Aylesford, Yalding, and Marden are three places particularly mentioned in the text, but not marked on Map.

The figures express the heights above *mean sea-level.*